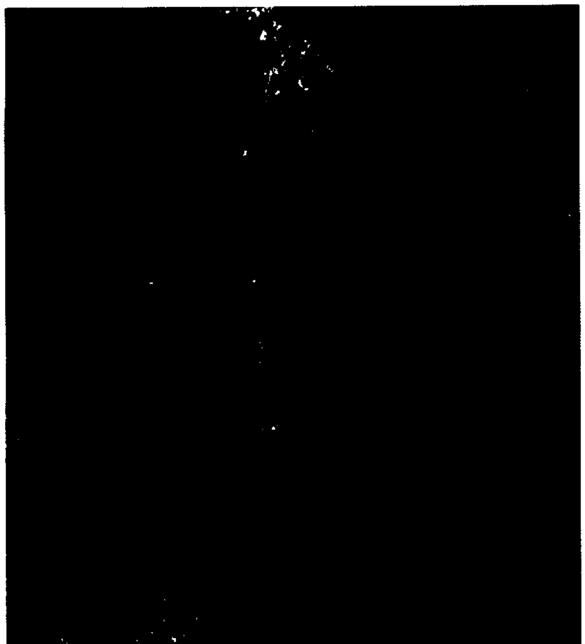
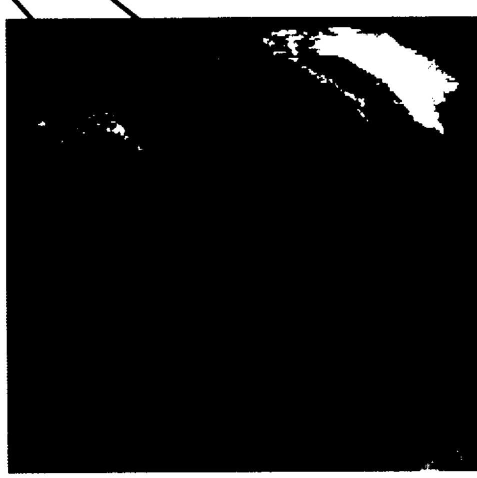
NAG9-1032

Validation of Land Cover Maps Utilizing Astronaut Acquired Imagery - Final Report





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June 1998-December 1999

Validation of Land Cover Maps Utilizing Astronaut Acquired Imagery Final Report

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6/23/98-12/31/98

I. INTRODUCTION

This report is produced in accordance with the requirements outlined in the NASA Research Grant NAG9-1032 titled "Validation of Land Cover Maps Utilizing Astronaut Acquired Imagery". This grant funds the Remote Sensing Research Unit of the University of California, Santa Barbara. This document summarizes the research progress and accomplishments to date and describes current on-going research activities. Even though this grant has technically expired, in a contractual sense, work continues on this project. Therefore, this summary will include all work done through and 5 May 1999.

The principal goal of this effort is to test the accuracy of a sub-regional portion of an AVHRR-based land cover product. Land cover mapped to three different classification systems, in the south-western United States, have been subjected to two specific accuracy assessments. One assessment utilizing astronaut acquired photography, and a second assessment employing Landsat Thematic Mapper imagery, augmented in some cases, high aerial photography.

Validation of these three land cover products has proceeded using a stratified sampling methodology. We believe this research will provide an important initial test of the potential use of imagery acquired from Shuttle and ultimately the International Space Station (ISS) for the operational validation of the Moderate Resolution Imaging Spectrometer (MODIS) land cover products.

II. METHODOLOGY

The methodology in this research employed several steps. The first was to select three different classifications created from the EDC Land Characterization Database. The classifications which were chosen include: (1) Olson's Global Ecosystems; (2) USGS Land Use/Land Cover System, Anderson et al.; and (3) International Geosphere Biosphere Program (IGBP) DIScover Land Cover Legend. The purpose of testing three different techniques was to attempt to establish, for the selected legends, which provides the best overall accuracy, which is best validated using Astronaut Acquired Photography, and which classes lend themselves to validation with Astronaut Acquired Photography.

The latter results are still being established, and are being accomplished via a rigorous cross-walking of the individual class legends for similarities and a statistical analysis of the accuracies in the individual classes in each legend. The second step involved the selection of randomly thrown sample points on the three classification schemes. These sample points were randomly selected by classes. In this study, we have attempted to achieve a sufficient number of samples within each study area to validate each class represented as 85% accurate at the 95% confidence level. This level of validation requires approximately 25 samples per class. We are attempting to validate 5 classes per legend. Thus, for each legend, there are 125 sample points, a total of 375 points for all three classification schemes.

The random sampling procedure has evolved into a two step process to take all bias out of this study. The first random selection is from the class list of each legend. Five classes were randomly selected from each legend's class list. A C-Program was employed for this task. The second random selection takes the output of the first program and applies only those classes chosen to a second program, written in Avenue, the programming language for ARC/VIEW. This program takes these classes, and selects 25 random locations of each class, in the western United States. An example of this output from this second program can be see in Figure 1.

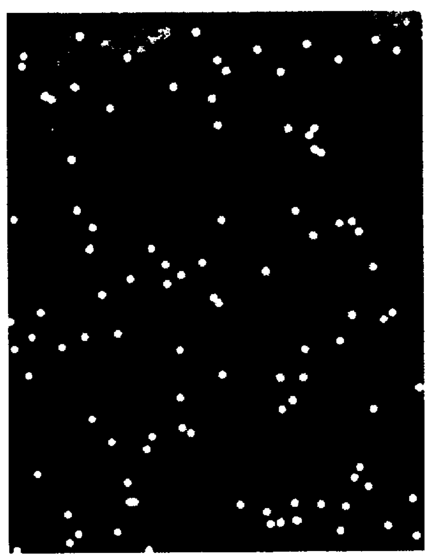

Figure 1. A random sample of 5 classes from the USGS Land Use/ Land Cover System, Anderson et al. Sample area is the Western United States.

The third step is to locate Astronaut Acquired imagery and Landsat TM imagery that fall over the selected points. From this a confusion matrix will be developed to better our understanding of the errors in this exercise. Taking this analysis further a Kappa statistic

will be established incorporating the results of the confusion matrix to yield a statistical comparison among the three resulting confusion matrices. The fundamental objective in this study is not to improve classification but to establish the potential of Astronaut Acquired photography for validating the land cover data product as compared to validations employing Landsat TM data.

III. RESULTS

The larger question initially posed before this research began was: "Does Astronaut Acquired Photography have the potential for validating land cover maps?" From the preliminary results of this research, the answer is yes. There are several steps which are necessary to bring the photography into a format which can then be analyzed and compared with satellite imagery. Landsat Thematic Mapper imagery also has several hurdles it has to be pulled over in order for it to be analyzed as well. These two sets of steps are not so dissimilar. The end result yields two sets of images falling over the sample point which can both aid in the validation of the land cover map.

Preliminary[1] results indicate that there is a tendency for a higher agreement between Shuttle Photography and Olson's Land Cover Legend than with any other legend, for most classes. Olson's Land Cover Legend has 94 different land cover classes, USGS Land Use/Land Cover has 24 and IGBP has 17 land cover classes. These initial results indicate that when there is a heterogeneous landscape, there is more agreement between the Astronaut Acquired Photography and Olson's Legend. Conversely, when there exists a heterogeneous landscape, there is less agreement between Astronaut Acquired Photography and USGS or IGBP Land Cover Legends. When the landscape tends toward only 1 or 2 land cover classes over large areas, such as in some southwestern states, there is high agreement between Astronaut Acquired Photography and all three land cover legends.

Comparing the value of Astronaut Acquired Photography against Landsat Thematic Mapper has become an interesting exercise. Landsat TM has a spatial resolution of approximately 30 meters x 30 meters. Astronaut Acquired Photography has a spatial resolution varying from 20 meters x 20 meters to 60 meters x 60 meters. Landsat TM has one look angle, Astronaut Acquired Photography usually has a wide variety of look angles. When the spatial scale between the two types of imagery is similar, the resulting class distinctions are also quite similar. Overall, introductory results verify that class discrimination between the two types of imagery correspond well. However, challenges arise when, even though the Astronaut Acquired Photography and the TM imagery show similar class differentiation, there is a large difference in "class scale" between the imagery and the land cover legends.

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[1] As indicated in Section II., there are a total of 375 sample points total, 125 per land cover map. There has been considerable time taken finding quality Shuttle Imagery for these sample points, as well as finding the Landsat Thematic Mapper images for these points.

IV. DISCUSSION

The Astronaut Acquired Photography used for this research is finely detailed in terms of being able to discern a very heterogeneous landscape. Initial results point to higher agreement between Astronaut Acquired Photography and a land cover legend which has a higher number of land cover classes. "Class scale" refers to an issue arising from these preliminary results. This term indicates that there is higher agreement between Astronaut Acquired Photography and a land cover legend which has a large number of classes versus a much lower agreement between Astronaut Acquired Photography and land cover legends which have relatively few land cover classes. The next step in this process is to begin to compare the Astronaut Acquired Photography to high aerial photography taken over the same sample points to further verify if the validation of the land cover legends with the Astronaut Acquired Photography is truly accurate.

V. CONCLUSIONS

While the findings presented here are preliminary we believe that further research will continue to confirm and expand upon the potential of astronaut acquired data to assist in the thematic accuracy validation process. There are still many sample points, which need verification on the three legends. This will be accomplished. When this study is complete, both a technical and general report will be generated from the results. This report will be forward to Johnson Space Center Technical Monitors and will detail our overall conclusions and recommendations for the application of our research findings and recommendations for future research in this area.

VI. PUBLICATIONS

This research has been documented in several ways:

(1) Gebelein, J. & Estes, J., 1999, "Validation of Earth Observations Using International Space Station", Conference on International Space Station Utilization, Institute for Space and Nuclear Power Studies, New Mexico.
(2) A conference presentation of the research described in the above paper (1) was presented at the Space Technology & Applications International Forum (STAIF-99), at the Institute for Space and Nuclear Power Studies, Albuquerque, New Mexico.
(3) Association of American Geographers published a list of abstracts as a supplement to the March AAG Newsletter. The abstract is titled: "Using Space Shuttle Imagery to Validate an AVHRR-Based Global Land Cover Map".
(4) A conference presentation of the research outlined in the above abstract (2) was presented at the Association of American Geographers 95th Annual Meeting, 23-27, 1999, Honolulu, Hawaii.

The documentation listed above is attached to this report.

Validation of Earth Observations Using International Space Station

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ABSTRACT

Accurate, up-to-date (science quality) land cover maps do not exist for most areas of the world. They do not exist at global scales; nor do they exist at continental, national, or local scales. This is equally true of both developed and developing nations. Land cover patterns on the surface of the Earth change. Some changes are rapid, such as urban sprawl. Other changes are slower such as the meandering of river channels consuming agricultural lands. Researchers at the University of California, Santa Barbara are working with colleagues at the University of Maryland, College Park; the United States Geological Survey, Earth Resource Observation System Data Center; and, the National Aeronautics and Space Administration (NASA) Johnson Space Center. We are proposing to test the capability of astronaut acquired photography to document and validate land cover change. Funding for the pilot phase of this project has been approved and research is underway to select appropriate sites in the Southern United States. The overall objects of this effort are: 1. Evaluate the potential of astronaut acquired data for the validation of land cover maps; 2. Determine to what extent astronaut acquired photography can assist in the identification of specific types of land cover change and the immediate local causes of such change; 3. Test the potential of astronauts to acquire photography to provide data concerning scientifically interesting and/or culturally significant ephemeral events; and, 4. Assist in the design for an upgraded Window Observational Rack Facility (WORF). The goal of this effort is to demonstrate the utility of ISS of the collection of information of value to researchers interested in documenting important land cover changes at scales from local to global. Using ISS data from tropical and mid latitudes combined with information extracted from polar orbiting satellites primarily from mid to high latitudes, we believe we can improve our ability to detect, document and validate important changes on the Earth's surface in a more timely and effective fashion. If proven correct, information generated could help environmental scientist, resource planners public policy decision makers and the public at large come to an improved level of understanding of the dynamic planet on which we live.

INTRODUCTION

Factual maps with known accuracy are required for a wide variety of scientific issues associated with the study of global environmental change (IGBP-DIS Working Paper #13, 1996). Global and continental scale land cover maps exist today. However, to date, there are neither regional nor continental global land cover maps of known thematic accuracy. Land cover data with known thematic accuracies do not exist for most regions of the globe (Running et al, 1995), (Estes, J. and Mooneyhan, W., 1994). The research discussed here is directed at assessing the potential for the use of Space Shuttle imagery to document and validate land cover change. Astronaut acquired photography will be employed in order to test the potential utility of data that may be acquired by astronauts employing the Window Observational Rack Facility (WORF) on International Space Station (ISS). Astronaut acquired photography is parallel to the WORF capabilities in terms of the visible spectrum as well as spatial resolution, this is illustrated below (Figure 1, Eppler, D., 1998). With this knowledge, how can we evaluate the potential of astronaut acquired data for the validation of land cover maps? Validation of large scale land use maps utilizing this type of imagery will be completed through a process of comparison among three different classification legends created from the Eros Data Center (EDC) Land Characterization Database. The purpose of the validation is to attempt to establish, for data thematically classified according to these selected legends, which provides the highest overall accuracy, which is best validated using astronaut acquired data and which classes lend themselves

to validation with astronaut acquired photography. Validation of land cover data is done using a stratified systematic sampling methodology.

INTERNATIONAL SPACE STATION

Earth Observations Data Characteristics Comparison

RESEARCH MISSION MANAGEMENT

- This chart shows that ISS capabilities will be complementary to other Earth observation data sources presently available to ESA researchers

	Resolution	Spectral Wavelengths
STS Handheld Photography	10-20 m	Visible, color infrared*
SPOT Image	20 m	0.5 - 0.9 μm
Landsat MSS Bands	80 m (visible) 240 m (thermal ir)	0.4 -1.1 μm 10.4 - 12.6 μm (LS 1-3)
Landsat TM Bands	30 m (visible) 120 m (thermal ir)	0.45 - 1.75 μm 10.4 - 12.5 μm
ISS Window	1-3 m†	≈0.3 - ≈1.0 μm (>70% transmission)

*spectral response based on film selected
† using a 20 cm optic

FIGURE 1. This shows that ISS Window facilities will be compatible with existing Earth Observing data sources currently accessible to scientists.

Actual validation involves the application of a multi-stage sampling frame employing the: AVHRR derived land cover data, Thematic Mapper data, Astronaut acquired photography and aerial photography as appropriate. The land cover legends used are the Olson Global Ecosystems legend, the International Geosphere Bioshpere Program legend (IGBP), and the Anderson legend. Fundamentally, this study attempts to determine whether and which individual land cover legends and classes therein are most amenable to validation utilizing photography acquired by the Shuttle crew. More specifically, this research tests the accuracy of a sub-regional scale portion of an Advanced Very High Resolution Radiometer (AVHRR) based global land cover map. This AVHRR based data result is utilized as a surrogate for land cover products to be derived from the Moderate Imaging Spectrometer (MODIS). The selection of study sites is dependent upon available Shuttle photography within the southern, conterminous United States. This research provides an important initial test of the potential use of imagery acquired from Shuttle and ultimately the International Space Station for the operational validation of MODIS land cover products.

BACKGROUND

"NASA astronauts began making earth observations with the first Mercury suborbital flight in 1961. The present working procedures, information, equipment, and training provided to orbital observers have been developed within NASA as a result of gradual operational improvements and scientific experimentation during the Mercury, Gemini, Apollo, Skylab, Apollo-Soyuz, and Space Shuttle Programs. The objective of these improvements over time has remained constant, that is, to enhance human capabilities to acquire scientifically meaningful and systematic Earth observations data while in orbit" (Helfert, 1989).

Astronaut preparation, in terms of taking photographs from Shuttle, begins on the ground with a preflight, Earth Observations Training Manual which gives detailed site descriptions of each location to be photographed. This manual splits the site descriptions into four major parts: significance of the site, physical characteristics of the site, observation techniques for the specific site, and a former Shuttle photograph of the site, if available (Earth Observations Training Manual, STS-51). They are then assisted by "phototrainers" who train the astronauts for earth looking as well as other looking photography. These "phototrainers" show the astronauts how to handle the cameras as well as the software which accompanies the instrument. A training manual, which details the hardware and software of camera operation, is taken onboard. When onboard the Space Shuttle, the astronauts have available to them an orbital chart of their

particular mission, which has the designated sites for the astronauts to focus on, highlighted. Onboard they also have a 1:10,000,000-scale atlas. Each day, they receive "flight notes" which include a weather satellite image showing where the least and most cloud-covered areas of the globe will be. This image translates into which designated sites will be available for photographing and which will not. The astronauts also receive daily updates on ephemeral events that require documentation (Lulla, pers. comm., 1998).

With this preparation, is it possible for this photography to provide information detailing scientifically significant and ephemeral events? In June 1991, Mt. Pinatubo, one of the 20 active volcanoes in the Philippine Islands, erupted. This was one of the largest global volcanic events of this century, and has recently been noted responsible for lowering global temperature. A photograph of Mt. Pinatubo and the surrounding area was taken by Shuttle crew in 1982 (STS3-10-567), before the eruption. The Space Shuttle Earth Observations Photography Database (SSEOP) has a series of post-eruption photographs of this volcano. The time series begins in December, 1991 (STS044-82-33) and continues at least until 1993 (STS055-151A-184, a 5-inch format color photograph, and STS055-86-118), a 70mm color infrared photograph). These series of photographs clearly document the large areal extent of the area directly affected by the blast, and those areas covered with ash. These images also reveal post-eruption effects such as the dispersal of the pyroclastic deposits, newly clogged drainages, and volcanic mudflow deposits. This time series is also being utilized to document the dispersal of debris, ash and mud flows around the mountain after two tropical storms and a second eruption in July 1992. The buildup of unstable volcanic debris and river valleys being filled to capacity with mud, combined with heavy rainfall can effect tremendous flooding (Lulla et al, 1993).

In terms of long term studies, Shuttle and Sklylab photography have been used to map the areal magnitude of Amazonian smoke palls linked to biomass burning (1973-1988). From these photos, Helfert and Lulla (1990) have been able to assess that the area surfaced by these smoke palls has expanded from approximately 300,000 sq km in 1973, to continental size smoke palls measuring nearly 3,000,000 sq km in 1985 and 1988. In Ecuador, photograph 4-61A-464-02 shows forest burning and valley pass smoke palls in the Andes Mountains due to burning for subsistence farming and isolated agriculture. This produces a unique form of altitudinal deforestation which occurs with a continuous increase in elevation of the bottom of the tree line to the mountain top (Helfert & Lulla, 1989). Biomass burning contributes a critical input to the total atmospheric budget of particulate and trace gases. Global deforestation and biomass burning commit possibly 15 percent of the present anthropogenic emissions of greenhouse gases (Andrasko et al, 1990).

The documentation of urban change in cities is another application of Shuttle photography and one of the major foci of this project. In spite of the fact that there are a multitude of consecutive, astronaut acquired photographs of cities as well as other areas around the world, there have been relatively few papers written in scholarly journals (Robinson, J. per. comm., 1998). The reason for this may be that only until recently has there existed a way for researchers to orthorectify space shuttle photographs. Once these photographs have been digitally orthorectified, they are useful for discovering phenomena of interest as well as gathering quantitative measurements of various regions of the Earth's surface (Zheng, Q., et al, 1997).

Cameras and photography techniques have improved since the days of the Mercury. These improvements allow astronauts to combine their photographic training with new developments in software which accompany the missions. For example, there is an onboard program, WORLDMAP, which prompts the astronauts to ready the cameras before the designated site comes into view (Reilly, J., pers. comm., 1998). The Hasselblad camera and video are always present on each mission. The Hasselblad lens has a 100 mm transparency with a 167x167 km coverage. A 250 mm transparency lens is also available which has 67x67 km coverage. The Linhof camera lens can have 75 mm, 135 mm, or 250 mm options with coverage of 361x483 km, 201x268 km and 108x145 km coverage, respectively (Lulla et al, 1996). Film types generally range from color infrared to color visible. There are many other cameras which have been flown experimentally and otherwise, but the scope of this study covers photographs using these types of film and instruments. The expertise of the Shuttle crew in terms of monitoring techniques, improved camera operations training and the increase in publications to document scientifically significant and ephemeral events proves that specific, quality studies can be conducted utilizing Shuttle imagery.

With this extensive ground training and onboard manuals, to what extent astronaut acquired photography can assist in the identification of specific types of land cover change and the immediate local causes of such change? This is an excellent lead-in to the importance of human controlled space photography. There has been a shift toward satellite digital imagery such as that afforded by Landsat, SPOT or NOAA Polar Orbiter's AVHRR. A marketing survey attests that approximately 74 percent of Landsat imagery is ordered as hardcopy photographs for end user photointerpretation (EOSAT, 1988). This means that experts are bringing to the table their photointerpretation skills, combining this proficiency with the expertise of a satellite analyst and producing scientifically acceptable output from orbital photographic analog data (Helfert, 1989). The advantage of human-controlled photography is multiple: observing an episodic event as it occurs and documenting it from several different angles or alerting scientists to undocumented human-induced change in regions hard to access on Earth are two such advantages. The *extent* to which Shuttle crew photography can assist in the identification of specific types of land cover change is part of the fact-finding mission of this study. Dr. James Reilly, who was part of the January/February, 1998 crew docking with the MIR Space Station related that forested terrain, grasslands, farmlands and deserts are very easy to pick out. He also pointed out that human modifications to an area, natural vegetation alteration, for example, are also easy to separate from the surrounding landscape. Dr. Reilly stated that if the air quality is good, with a 400 mm lens it is possible to see detail to the level of a city block, or individual buildings, depending on the altitude (Reilly, J., pers. comm., 1998). Using this level of detail, and the capability of astronauts to take a mosaic of photographs to cover the entire designated site, we are testing these abilities by specifying precise points in the western United States which will be incorporated into the Earth Observation Manual of the most appropriate Space Shuttle mission. Once designated sites have been photographed and downloaded from the NASA/Johnson Space Center Space Shuttle Earth Observations Database, there is a several step process to take the testing of Shuttle photography one step further and assess its potential for the validation of large-scale, land cover maps.

ISS can be an important platform for the conduct of remote sensing research of the Earth's surface. The Window Observation Rack Facility (WORF) is a facility which will utilize a high optical quality, nadir-looking window specialized for the deployment of Earth and space science equipment in a pressurized setting. The spatial resolution of the WORF will be 1-3 meters, using a 20 cm optic. The spectral wavelengths of the window will be ~0.3-1.0 μm (>70% transmission). This optical quality will make the resulting images complementary to other, existing imagery already available such as STS Handheld photography, SPOT satellite imagery, and Landsat MSS (multispectral) &TM satellite imagery (See Figure 1). The laboratory research window transmission curve is shown below (Figure 2, Eppler, D.).

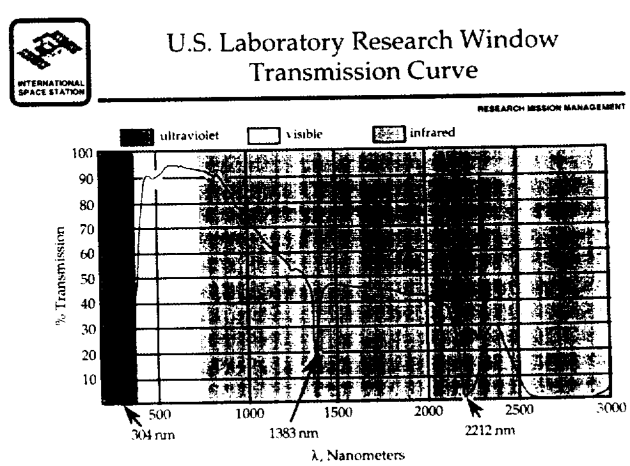

FIGURE 2. Shows that not all wavelengths of ultraviolet through the infrared, transmit through the window uniformly. This also reveals the "atmospheric windows" where wavelengths are transmitted most readily through the research window.

Since the launch date for the assembly of the WORF is currently scheduled for November, 1999, on flight 7A.1, the timeliness of this research is clear. Currently, "the United States Laboratory WORF is in the requirements definition and conceptual design phase. Many aspects of the Space Shuttle-based Earth Observation Program will be considered in the design and operation of the WORF" (http://station.nasa.gov/science/disciplines/earth/index.html).

METHODOLOGY

The large-scale, land cover map used in this research is an AVHRR-based global land cover map produced by researchers at the U.S. Geological Survey (USGS) and Earth Resources Observation Systems (EROS) Data Center (EDC) in Sioux Falls, South Dakota. The EDC Land Characterization database demonstrates that multitemporal AVHRR (Advanced Very High Resolution Radiometer) data, augmented by ancillary data and examined in a structural manner, can be utilized to characterize land cover (Loveland et al, 1991). A set of 28-day maximum NDVI (Normalized Difference Vegetation Index) composite images covering the conterminous United States were clustered, refined, and labeled using ancillary data. The product was a 159-class land cover characterization database. This AVHRR-based product is being employed as a surrogate for land cover products which will be derived in the future from the Moderate Resolution Imaging Spectrometer (MODIS).

Using this AVHRR-based data product, the first step in our research encompasses land cover mapped in three different classification systems of southwestern United States test sites which will be sub-setted from the EDC Characterization Database. The purpose of testing three separate techniques is to attempt to establish, for the selected land cover legends: 1. which provides the highest overall accuracy; 2. which is best validated using astronaut acquired data; and 3. which land cover classes lend themselves to validation with astronaut photography. Currently, we are working with Olson Global Ecosystems database (Olson et al, 1983), USGS Land Use/Land Cover System (Anderson et al, 1976) and the International Geosphere Biosphere Program (IGBP) DIScover Land Cover Legend (Belward, A. and Loveland, T, 1995). Classes determined appropriate for validation with Shuttle photography will be accomplished by a rigorous comparison of individual class legends for similarities and a statistical analysis of the accuracies of the individual classes in each legend.

The second major step involves the selection of randomly thrown sample points on the three selected classification schema. These sample points will be randomly selected by classes (these are mentioned above). In so far as practical, we will attempt to achieve a sufficient number of samples within each study area to validate each class represented as 85 percent accurate at the 95 percent confidence level. This will entail the verification of some 25 samples per test site, per class.

The third step is to locate past Shuttle crew photography and incorporate those points chosen, into an appropriate upcoming mission's Earth Observations Training Manual. In addition to this photography, it is also essential to locate Landsat Thematic Mapper (TM) imagery that falls over selected sample points. We will then use expert image analysis in assessing whether the classes mapped at the classes interpreted at each sample site for each type of imagery. From this analysis a confusion matrix will be developed to aid in understanding the nature of the errors involved in this exercise. In addition, for approximately 10 percent of the total samples, we will attempt to acquire and interpret classes from high altitude aerial photographs or surface sampling. Thus, we will be validating the large-scale land cover map with astronaut acquired imagery, Landsat TM imagery and, for a limited sample, high altitude aerial photography or surface verification, if at all possible.

The final step in this methodology will involve a thorough analysis of the successive interpretation of astronaut acquired imagery and Thematic Mapper imagery for this potential utility in the process of validating the three selected thematically classified land cover products. In addition to this we will use the validation of the interpretations of these data employing high altitude aerial photography or field survey where available or possible. The overall objective of this research is to demonstrate the immediate utility of Shuttle imagery, and ultimately, ISS (International Space Station) Earth Observation imagery for ephemeral and long-term studies of the Earth's changing surface.

CONCLUSIONS

The world is in a constant state of change. As Earth's population continues to grow it is important that we have accurate, timely information with which we can assess the status of our environment. In order to effectively and efficiently assess the accuracy of regional and continental global land cover maps and to identify change we must employ advanced technology and innovative methodologies. Using ISS in combination with polar orbiting instruments we will have an improved capability to evaluate and validate land cover products. Employing valid sampling strategies we can acquire the data needed to determine within known confidence limits the thematic accuracy of the map products upon which decision may be based. Using these products, scientists and policy-makers will have improved tools with which to make informed judgements of issues that effect us all.

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Validation of Earth Observations Using International Space Station

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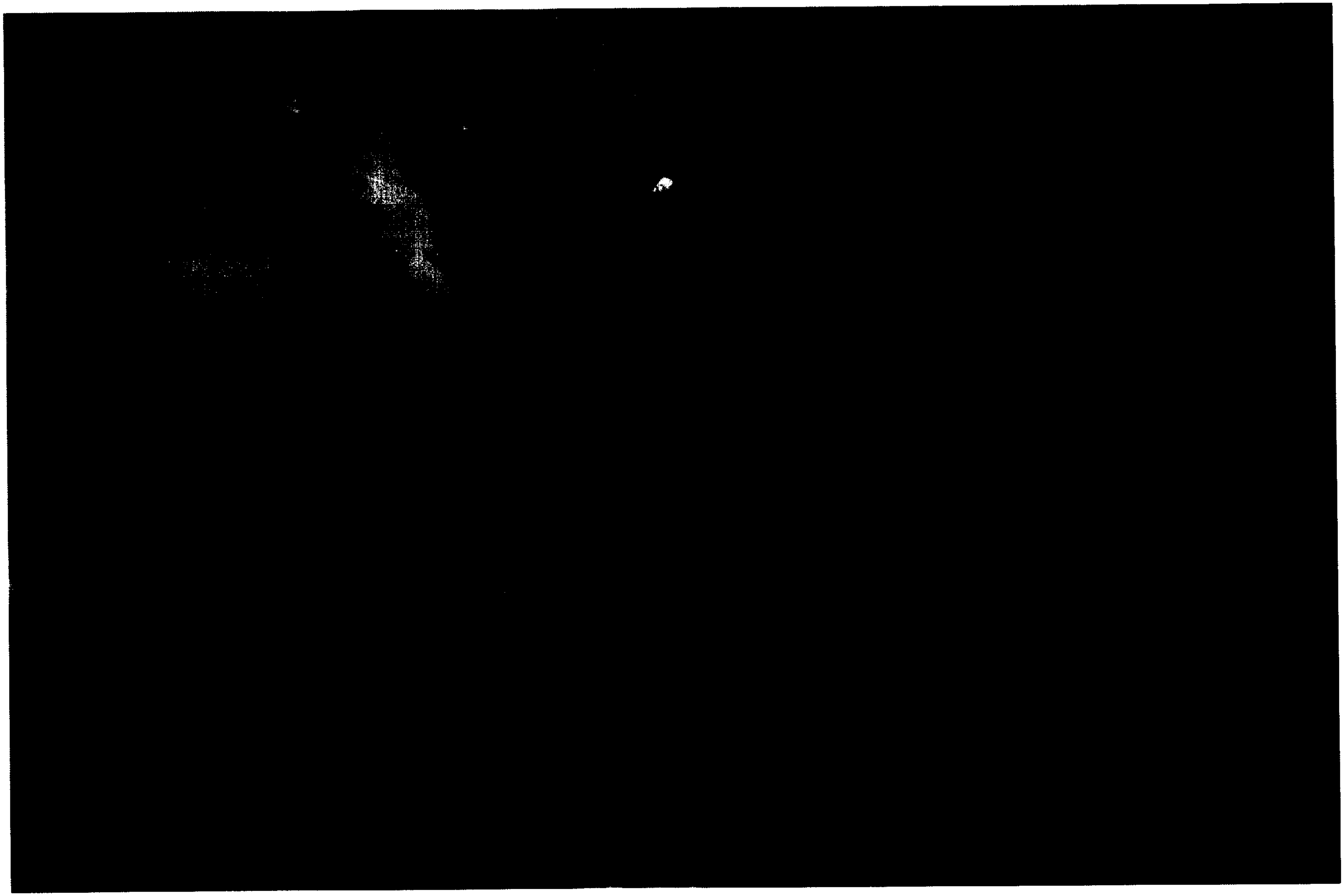
Overall Objectives of Research

- Evaluate the potential of astronaut acquired photography for validation of land cover maps
- Determine to what extent astronaut acquired photography can assist identification of land cover types, change and immediate causes of change
- Test potential of astronauts to acquire photography of culturally significant ephemeral events
- Assist in the design for an upgraded WORF

Astronaut Acquired Photography

- Astronaut acquired photography assists in identification of land cover, land cover change and immediate causes of such change
- How has photography improved?
- How do the Shuttle's camera observation characteristics parallel current sensors?
- Astronaut acquired photography provides data on significant and ephemeral events

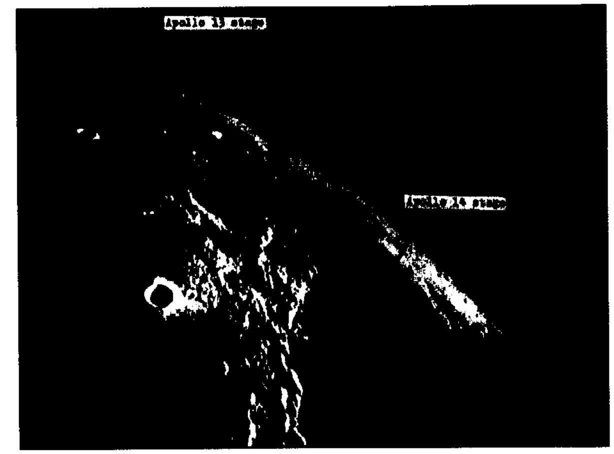
Kuwait Oil Fires - April, 1991



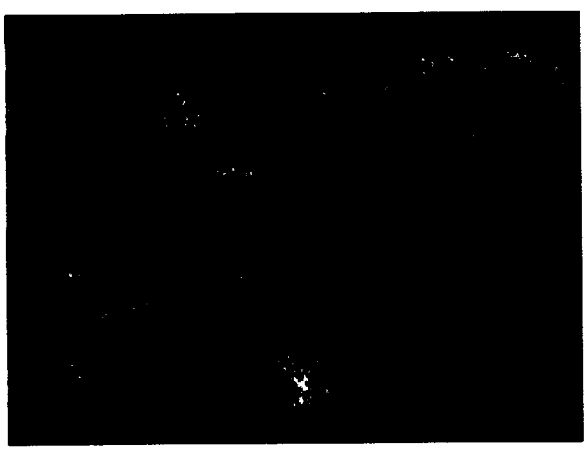
Earth Observation History

Mercury - Ganges Delta, 1963

Gemini - Nile, 1966



Apollo - Lunar Mission,1972



Skylab - Tibet, 1973

Apollo-Suyez - Chesapeake Bay, 1975

Space Shuttle - Great Salt Lake, 1990

INTERNATIONAL SPACE STATION

Earth Observations Data Characteristics Comparison

- This chart shows that ISS capabilities will be complementary to other Earth observation data sources presently available to ESA researchers

	Resolution	Spectral Wavelengths
STS Handheld Photography	10-20 m	Visible, color infrared*
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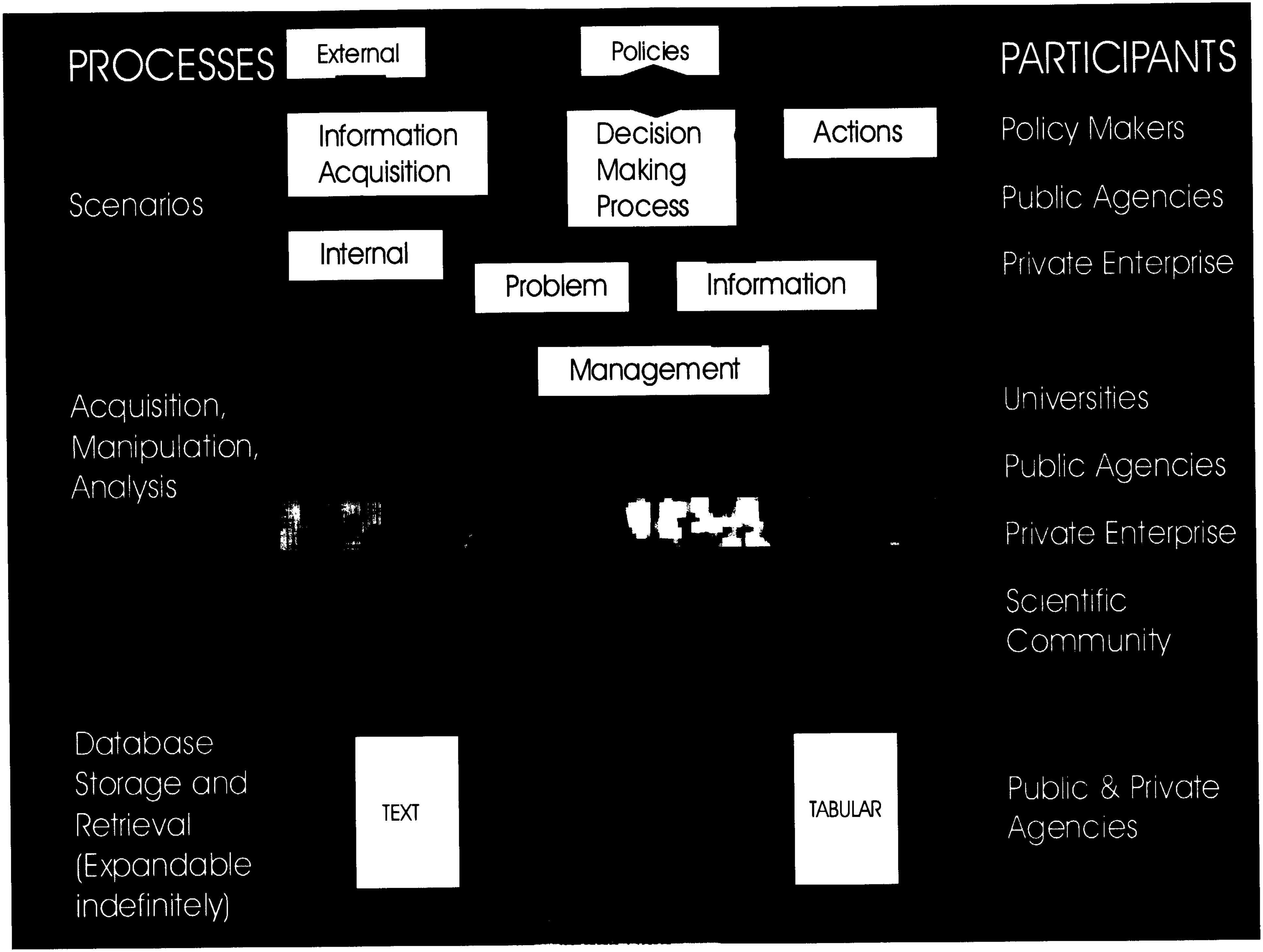
PROCESSES
External
Policies
PARTICIPANTS
Information Acquisition
Decision Making Process
Actions
Policy Makers
Scenarios
Public Agencies
Internal
Problem
Information
Private Enterprise
Management
Acquisition, Manipulation, Analysis
Universities
Public Agencies
Private Enterprise
Scientific Community
Database Storage and Retrieval (Expandable indefinitely)
TEXT
TABULAR
Public & Private Agencies

Current State of Validation

- No regional or continental scale land cover maps of known thematic accuracy exist
- Only one global scale product "done" using State of Practice methodology
- IGBP Validation Efforts
- Accurate, Up-To-Date land cover maps do not exist

International Geosphere Biosphere Programme
Land Cover Class Sample Distribution

Validation Research

- Sensor Products for Validation
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  - Employing Landsat TM and aerial photography we will test the accuracy of a subset of AVHRR based land cover map
- Accuracy Assessment Procedures
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Classification Legends

IBGP Legend, North America

Olson's Legend, North America

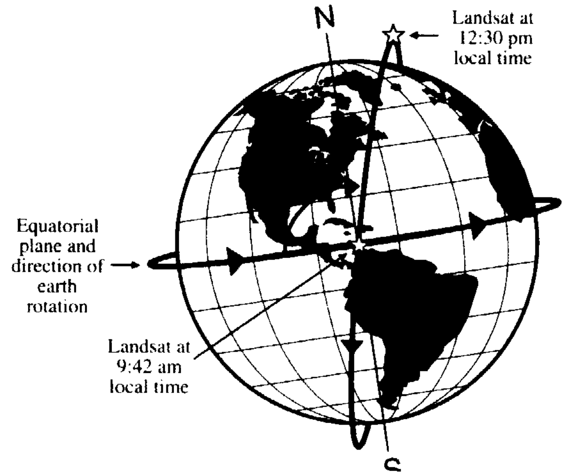
Validation Focus

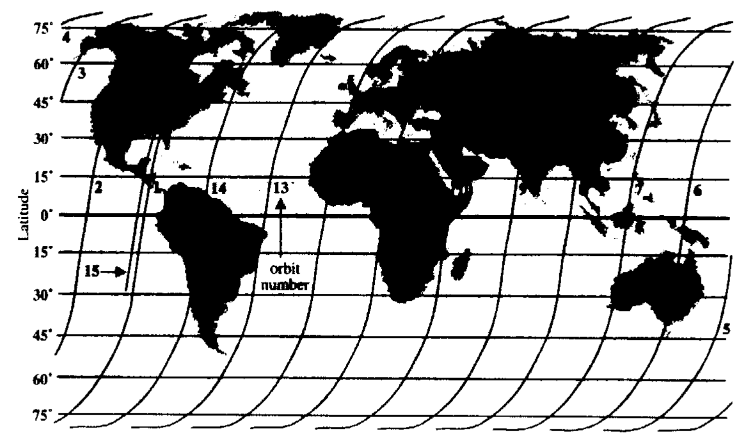
- Evaluate potential of astronaut acquired data for the validation of land cover maps
- Assess ability of Space Shuttle imagery to document and validate land cover change
- Examine use of astronaut acquired data to identify causes of change

ISS Capabilities Complementary to Existing Sensor Coverage

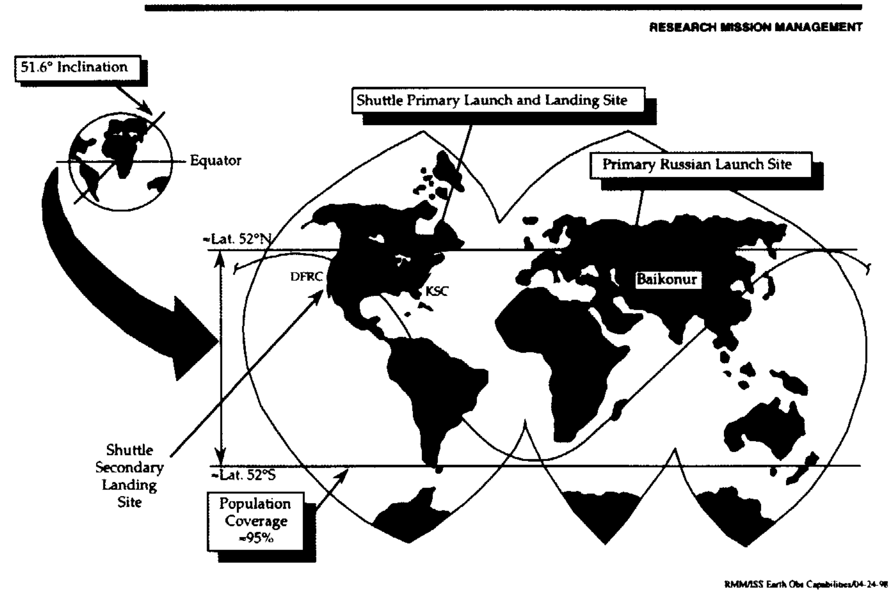
- Polar orbiting satellites and ISS
- Transmission & spectral regions of ISS Window and existing sensors
- Human controlled coverage (ISS)
- Through experience, improved earth observing capabilities will allow better understanding and documentation through constant manned observation

Landsat Orbital Track





ISS Orbital Ground Track



Significance of This Research

- Demonstrate potential of Astronaut Acquired Data
- Rapid and efficient evaluation of land cover products
- Improve WORF characteristics to better meet community needs

USING SPACE SHUTTLE IMAGERY TO VALIDATE AN AVHRR-BASED GLOBAL LAND COVER MAP

Jennifer Gebelein, Department of Geography, University of California, Santa Barbara, California, 93106

Land cover data with known thematic accuracies do not exist for most regions of the globe (Estes, J. and Mooneyhan, W., 1994). The research discussed here is directed at assessing the potential for the use of Space Shuttle imagery to document and validate land cover change. More specifically, this study reviews the methods developed for validating an AVHRR (Advanced Very High Resolution Radiometer)-based global land cover map with astronaut acquired imagery. For comparison, we will also be utilizing Landsat Thematic Mapper (TM) imagery and, for a limited sample, high altitude aerial photography for surface verification. The land cover map used in this study is an AVHRR (Advanced Very High Resolution Radiometer)-based global land cover map produced by researchers at the U.S. Geological Survey (USGS) and Earth Resources Observation Systems (EROS) Data Center (EDC). The methods involved are based on testing three different land cover legends for 1. which provides the highest overall accuracy; 2. which is best validated using astronaut acquired data; and 3. which land cover classes lend themselves to validation with astronaut photography. Classes determined suitable for validation with Shuttle imagery will be assessed by a rigorous comparison of individual class legends for likeness and a statistical summary of the accuracies of the individual classes in each legend. A confusion matrix will be developed to aid in understanding the omission, comission, and correctly mapped portions of the selected classes. A second statistical test, an adaptation from the Kappa statistic, will also be utilized to assess the error and accuracy of Shuttle imagery potential. This study will test the capability of astronaut acquired photography to document and validate land cover change.

Using Astronaut Acquired Photography to Validate AVHRR-Based Land Cover Maps

Jennifer Gebelein
University of California
Remote Sensing Research Unit
Santa Barbara, California

Outline

- Introduction
- Background
  - Current State of Validation
  - Research Objectives
  - Astronaut Acquired Photography
- Research Rationale
- Validation Research Steps
- Expected Results

Current State of Validation

- Accurate, Up-To-Date land cover maps do not exist

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Overall Research Objectives

- Extend IGBP Validation Effort
- Determine which AVHRR-Based land cover legend produces highest overall accuracy
- Establish degree to which land cover legends can be validated using astronaut acquired photography
- Conclude which specific land cover classes lend themselves to validation with astronaut acquired photography

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Astronaut Acquired Photography

➡ Astronaut photography evolution

- How the Shuttle's camera observation characteristics parallel current sensors

- Astronaut acquired photography assists in identification of land cover, land cover change and immediate causes of such change

- Astronaut acquired photography provides data on significant and ephemeral events

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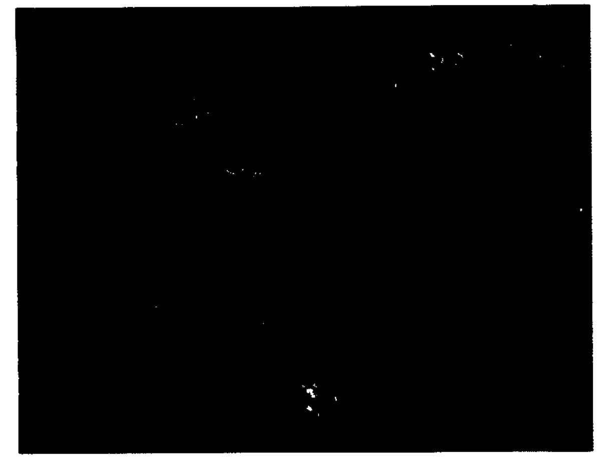
Earth Observation History

Mercury - Ganges Delta, 1963

Gemini - Nile, 1966



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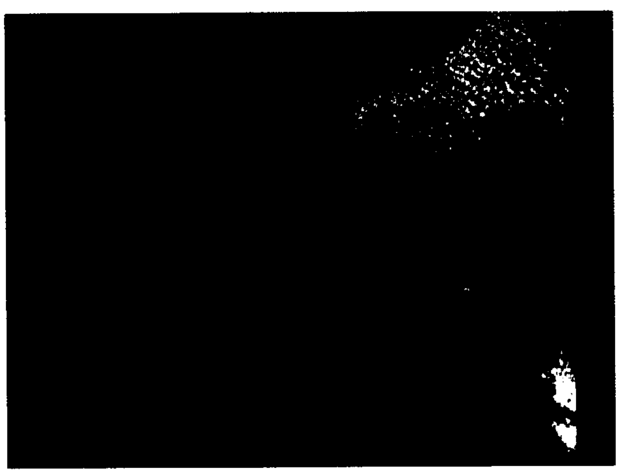

Space Shuttle - Madagascar,
Onilahy River, 1982

Space Shuttle - Great Salt Lake,
1990

Space Shuttle - Bora-Bora,
1994

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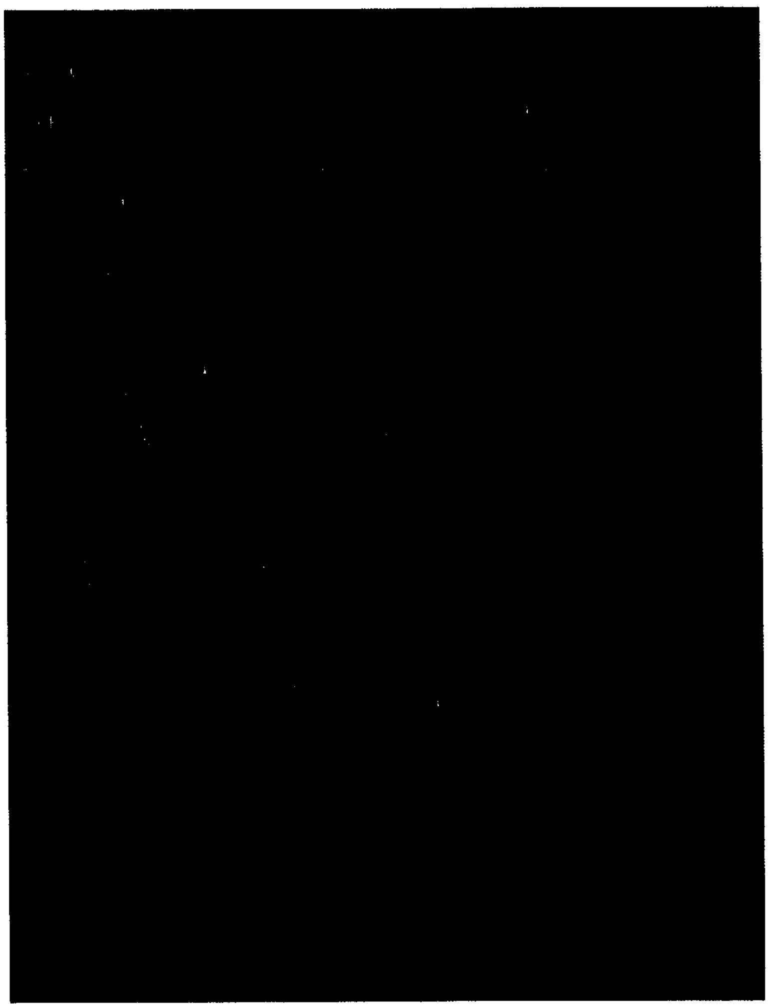
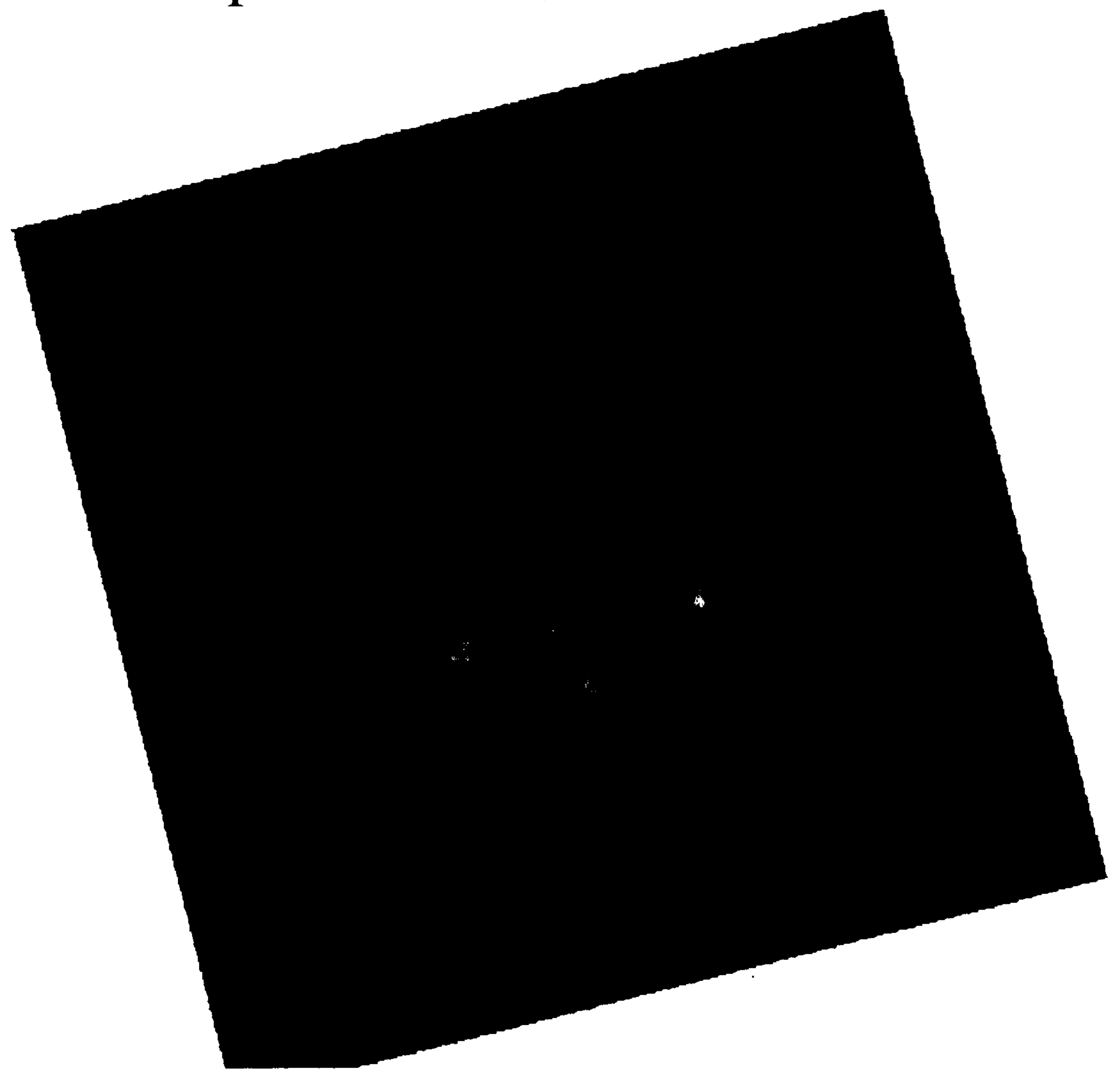
Algeria, Tifernine Dunes

Gemini, 1965



Space Shuttle, 1995



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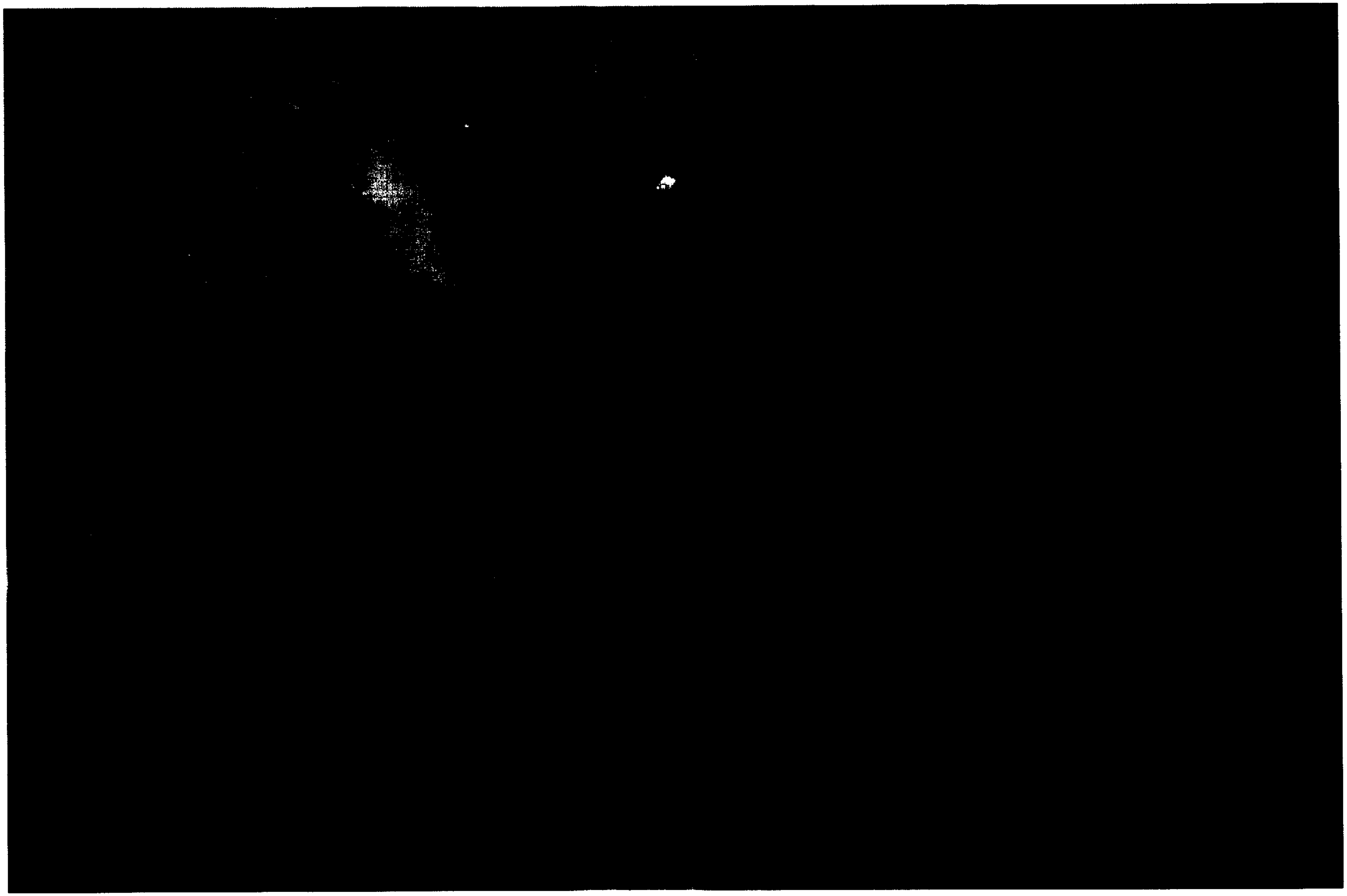
Kuwait Oil Fires - April, 1991

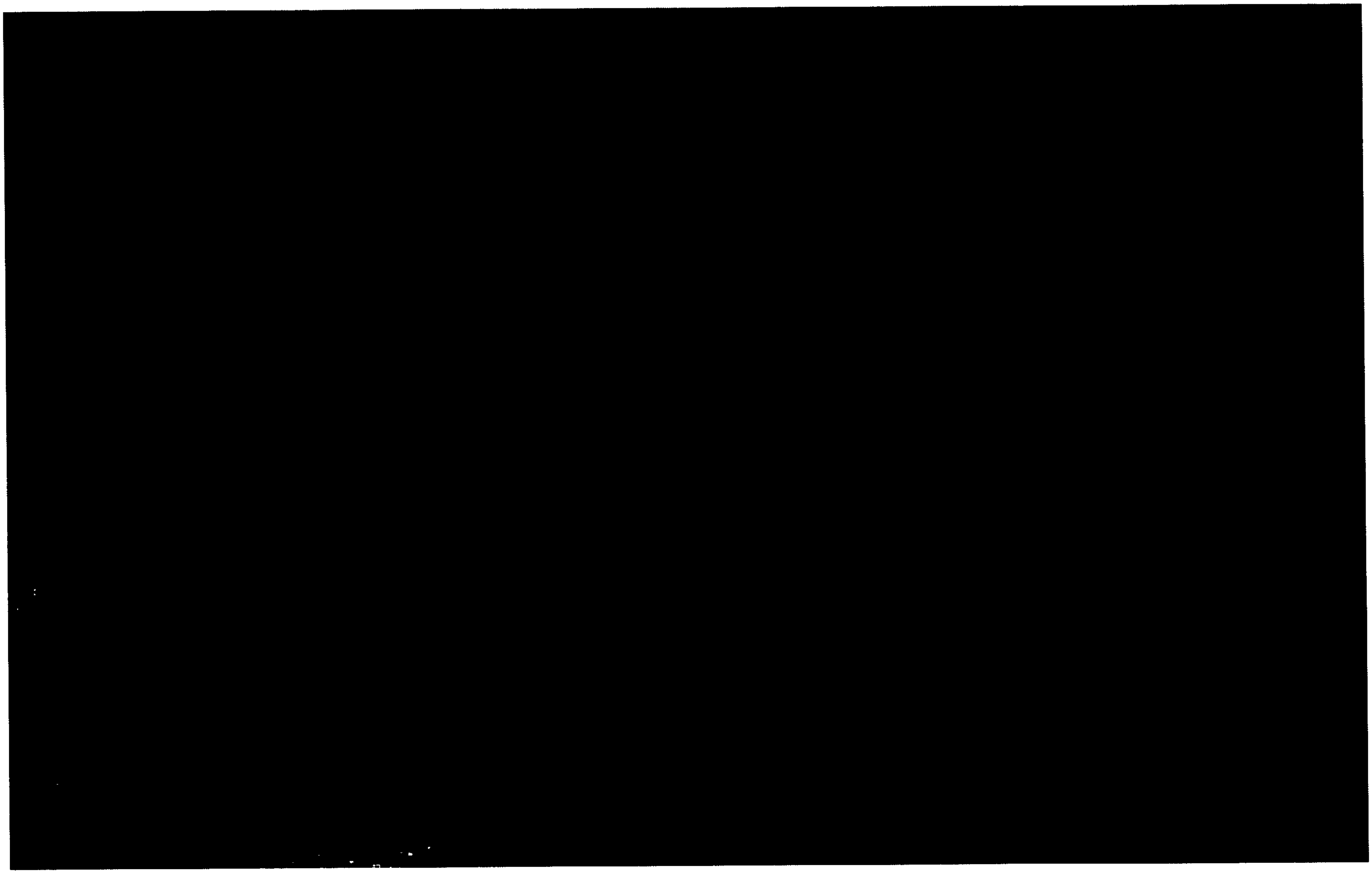


Internal Waves

Indian Ocean, November 1991

Mississippi River Delta and Coastal Louisiana, January 1985

Sediment pattern caused by near-shore water currents



Volcano, Kyushu, Japan
October 1993

Klyuchevskaya Volcano
Kamchatka Peninsula
Russia, October 1994

Research Rationale

- To increase accuracy of land cover products
  - Need to collect data of sample sites
  - Need to acquire data as near to dates of base map product as possible
- Why use astronaut acquired photography from ISS?
  - Receiving station and cloud cover can limit acquisition
  - ISS has high repeat coverage in tropics

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Validation Research

- <u>Sensor Products for Validation</u>
  - An AVHRR based product is being utilized as a surrogate for MODIS derived land cover products
  - ISS Capabilities complementary to POP
  - Employing Landsat TM and aerial photography we will test the accuracy of a subset of AVHRR based land cover map

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ISS and POP Capabilities Complementary

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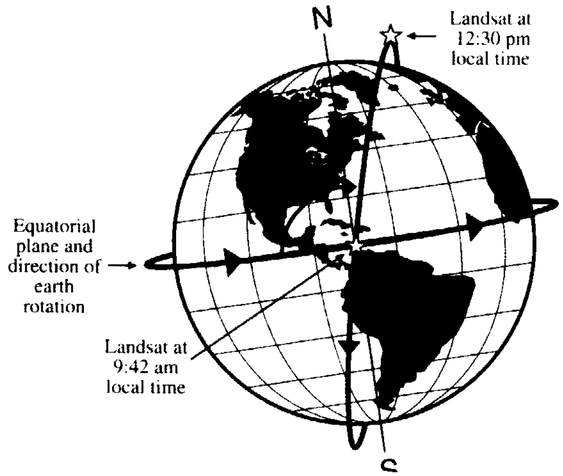
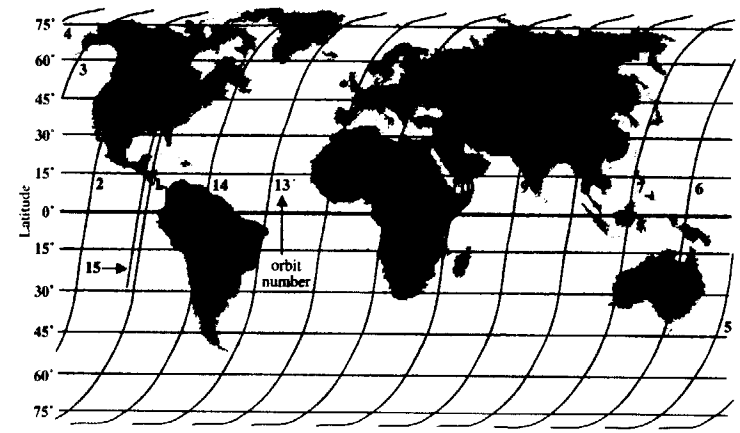
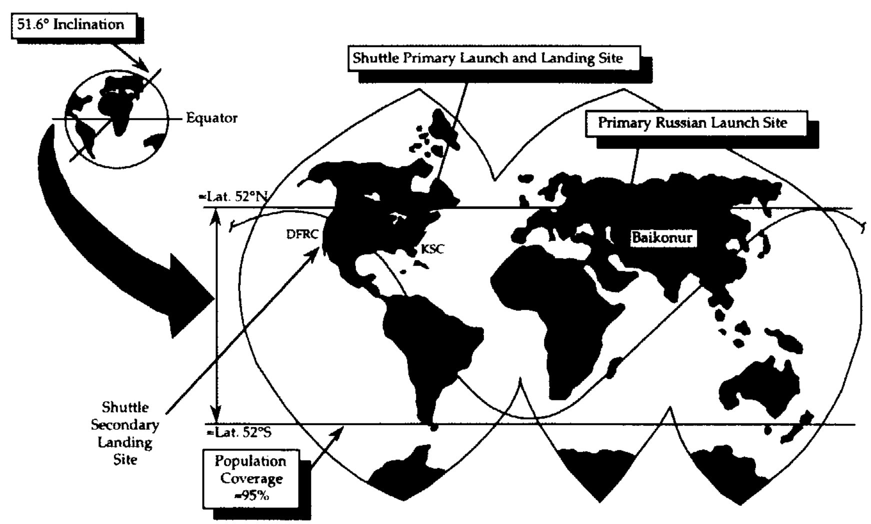
Landsat Orbital Track





ISS Orbital Ground Track



Validation Research

- Sensor Products for Validation
  - An AVHRR based product is being utilized as a surrogate for MODIS derived land cover products
  - ISS Capabilities complementary to POP
  - Employing Landsat TM and Shuttle photography tests of the accuracy of a subset of AVHRR based land cover map will be accomplished

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Validation Research

- <u>Accuracy Assessment Procedures</u>
  - Sub-set 3 Different Classification Legends
  - Selection of randomly thrown sample points
  - Incorporate points chosen into an upcoming mission’s Earth Observations Training Manual
  - Acquire Imagery
  - Interpret Sample Points
  - Construct Confusion Matrices
  - Analyze Results
  - Produce Conclusions

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IBGP
Legend
Olson
Legend
Anderson
Legend

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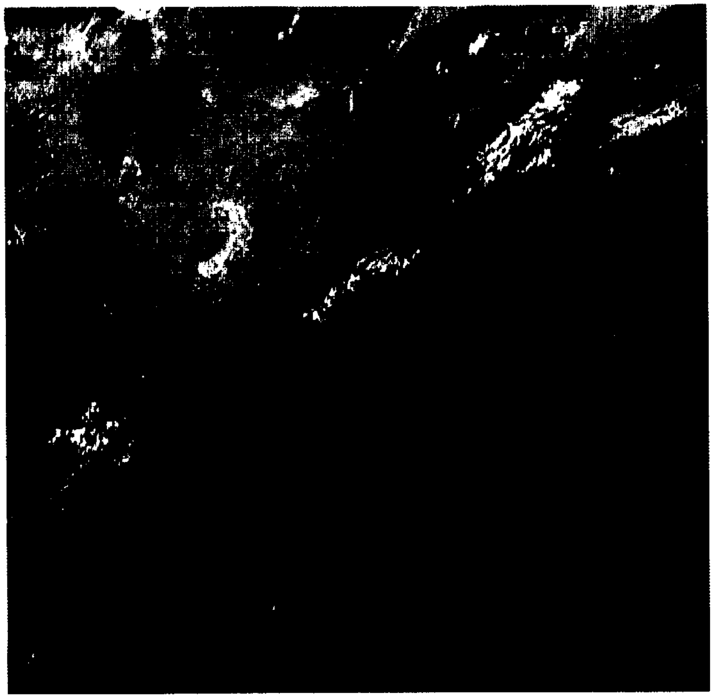
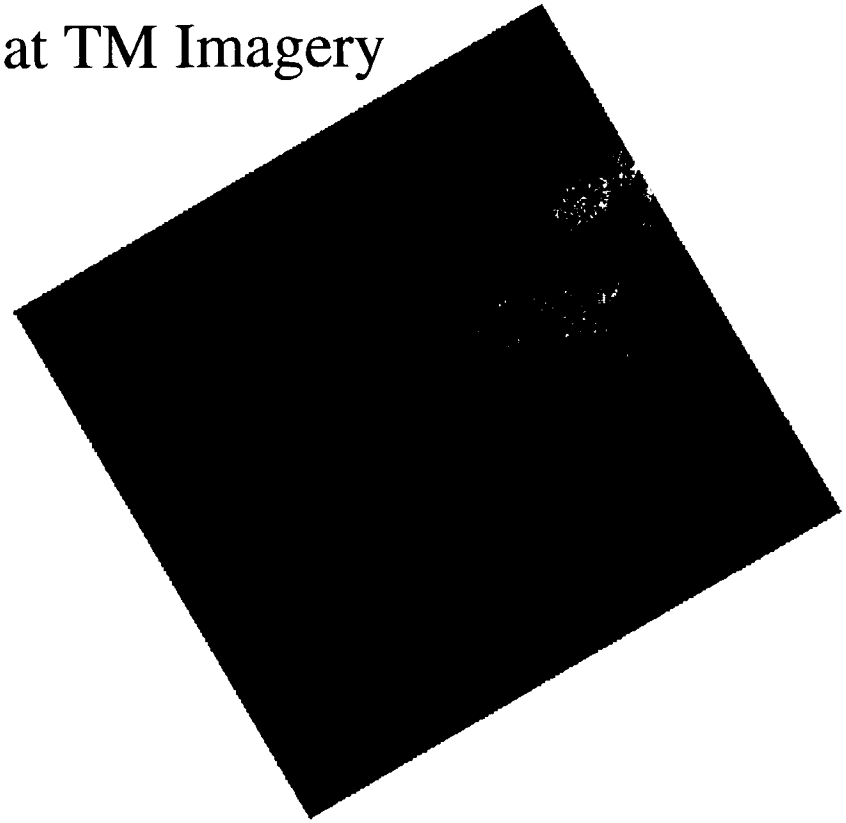
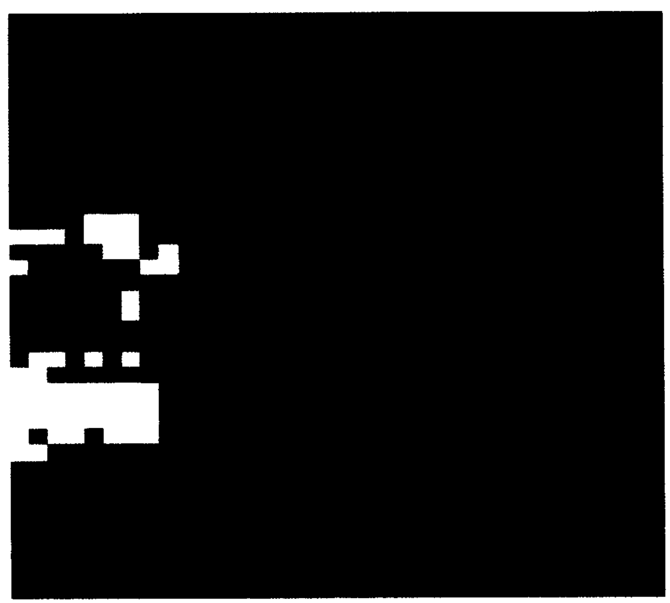

Shuttle Photography

Landsat TM Imagery



Anderson Legend

Expected Results

- Extend results of IGBP Validation
- Determine which land cover legends are most amenable to validation with astronaut acquired photography
- Determine which land cover classes are defined most accurately via astronaut acquired photography

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Significance of This Research

- Demonstrate potential of Astronaut Acquired Data
- Potentially improve ISS WORF characteristics to better meet community needs
- Rapid, efficient, operational evaluation of land cover products
- Improved Decision Making
- Potential for more operational validation

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